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Merging Galaxies in Isolated Environments II.

Evolution of Star Formation and Accretion Activity during the Merging Process

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ABSTRACT

Context. It is now well known that certain massive galaxies undergo enormous enhancements in their star formation rate (SFR) when they undergo major mergers, as high as 100 times the SFR of unperturbed galaxies of the same stellar mass. Previous works found that the size of this boost in star formation (SF) is related to the morphology of and the proximity to the companion. The same trend has also been observed for active galactic nuclei (AGN) fraction, where galaxies which are closer together tend to have higher AGN fractions.

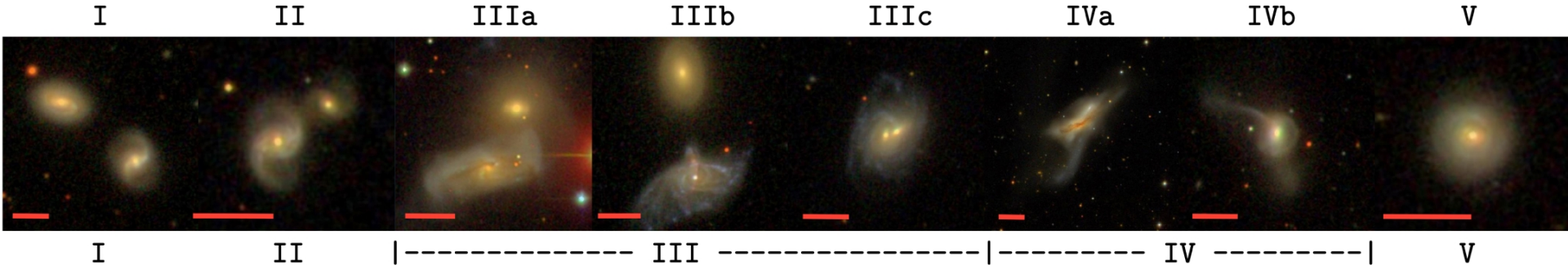
Aims. We aim to analyse the SF enhancement and AGN fraction evolution during the merger process, using a more timeline-like merger sequence. Additionally, we aim to determine the relation between the SF enhancement in mergers and the morphology of the galaxies involved.

Methods. Taking advantage of the stellar masses (M_*) and SFR of ~600 nearby isolated mergers obtained in our previous study, we calculate the distance of each of our galaxies from the star-forming main sequence (MS, sSFR/sSFR$_{MS}$), which we refer to as the SF mode. We then analyse how the SF mode varies during the merger process, as a function of morphology and M_*. Additionally, we analyse the AGN content of our mergers, using multiple diagnostics based on emission line ratios and WISE colours.

Results. We observe that, overall, merging galaxies show a SF mode that is governed by their morphology. Spirals typically show high SF mode values while highly-disturbed (HD) galaxies are generally even more enhanced (median values of +0.8 dex and +1.0 dex above the MS, respectively). On the contrary, elliptical and lenticular galaxies show the lowest SF modes, as expected. However, even they show SF enhancement compared to their unperturbed counterparts. For example, their median SF mode is just within the 1-sigma scatter of the MS, and this can occur even before the galaxies have coalesced. We see a trend for SF mode to gradually increase with increasing merger stage. We do not find a clear dependency of the observed AGN fraction on merger stage for the majority of our classification methods.

Conclusions. We find mergers can significantly enhance SF in galaxies of all morphologies. For early-type galaxies, this could suggest

Последовательность мержеров: 540 объектов



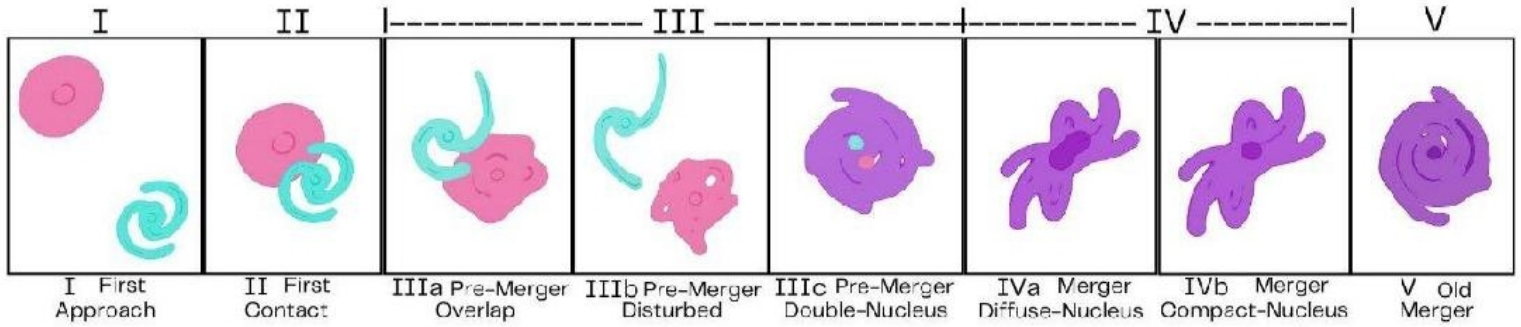


Fig. 1. Cartoon representing the Merger Stages classification used in this work. I (First Approach): the two galaxies are clearly separated but approaching to each other, following our Δv_{rel} condition. II (First Contact): the two galaxies are overlapping with no strong perturbations. IIIa (Pre-Merger Overlap): the two galaxies are overlapping and showing strong perturbations. IIIb (Pre-Merger Disturbed): the two galaxies are clearly separated but showing strong perturbations. IIIc (Pre-Merger Double-Nucleus): there is only one very perturbed object clearly showing two nuclei. IVa (Merger Diffuse-Nucleus): one very perturbed object with a very diffuse nucleus. IVb (Merger Compact-Nucleus): one very perturbed object with a very luminous and compact nucleus. V (Old Merger): one galaxy with no strong perturbations but disturbed central morphology.

Характеристики выборки

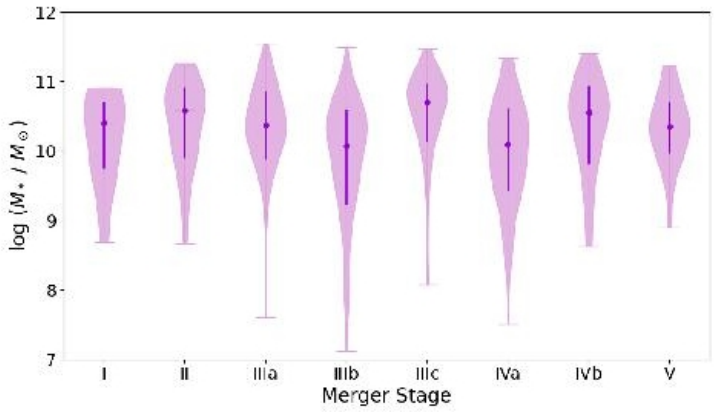


Fig. 2. Violin-plot of the stellar masses according to merger stage. **The shaded regions show the smoothed normalised number distribution.** The filled circles and bold lines indicate the median and one-sigma percentile, respectively.

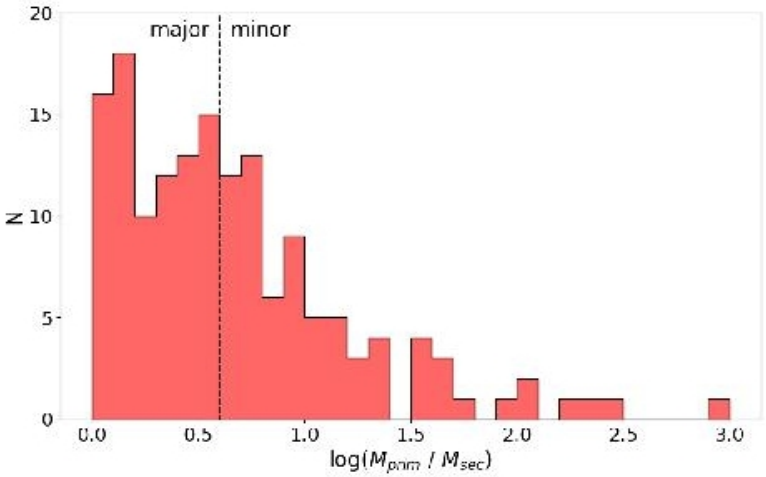


Fig. 3. Stellar mass ratio between the primary and the secondary component of the mergers showing two separated components.

Результаты: звездообразование

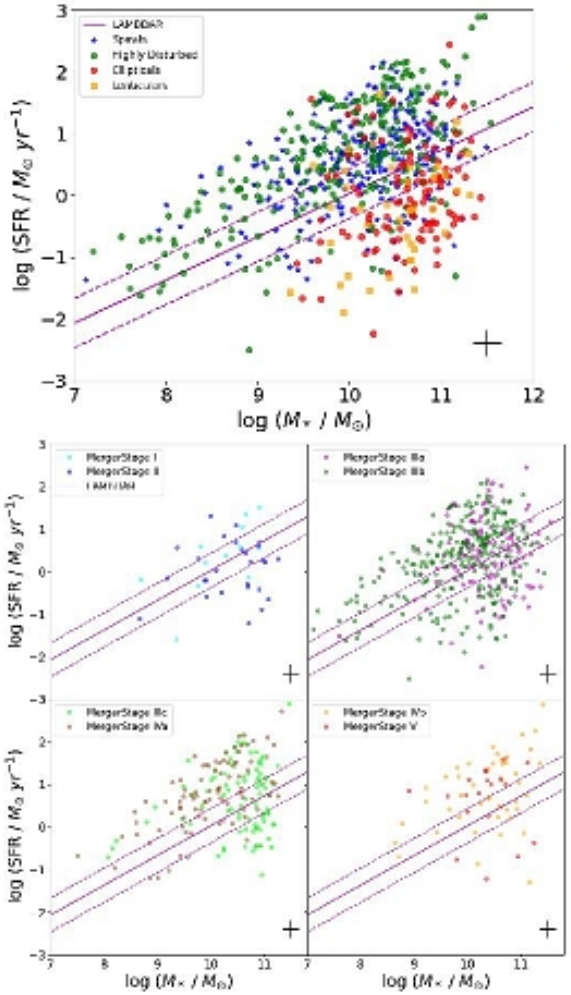


Fig. 4. SFR-M_* plane separated by morphology (top panel) and merger stage (bottom panels). The solid- and dashed-magenta lines represent the MS and the scatter (see text). The typical error is shown on the bottom-right corner of each panel.

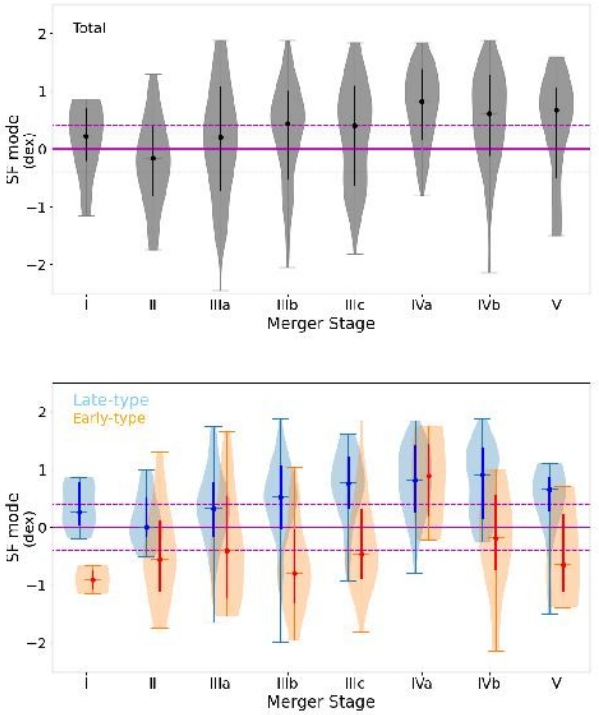
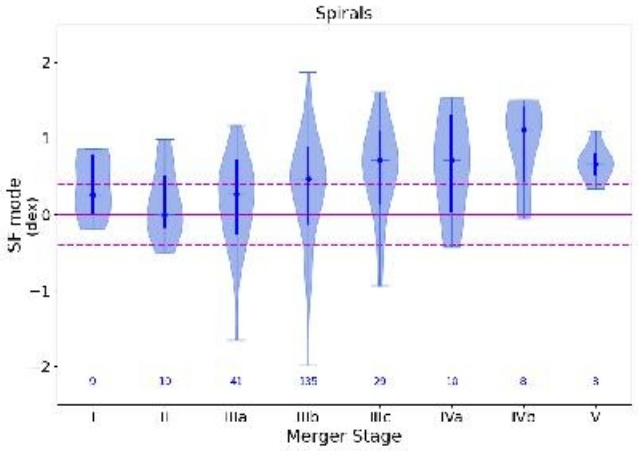
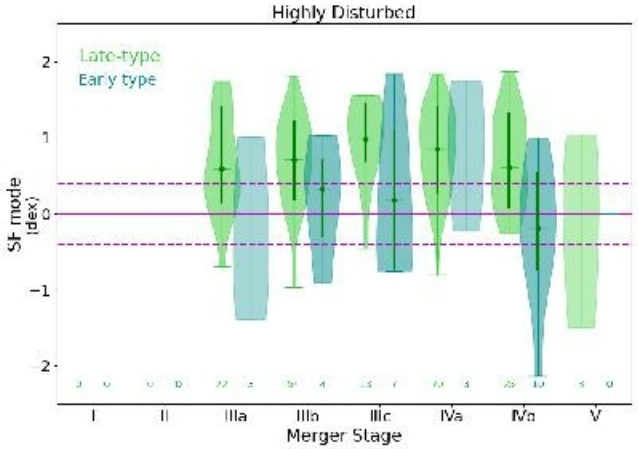
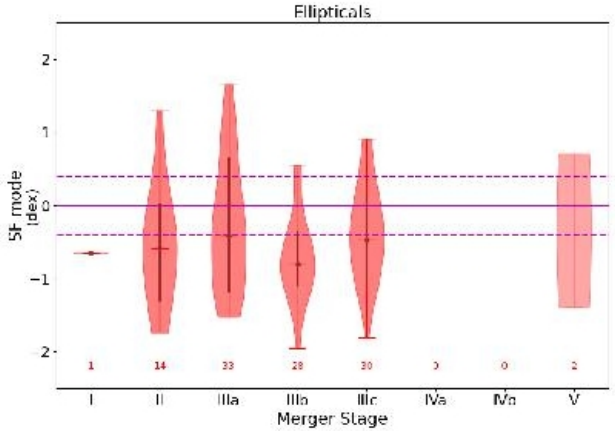


Fig. 5. Star formation mode distribution in each merger stage. The filled circle indicates the median and the bold lines show the percentile including 34% of objects from each side of the median (equivalent to one-sigma). The horizontal solid- and dashed-magenta lines represent the MS. The top panel shows the SF mode distribution of the entire sample. The bottom panel shows the SF mode distribution of the merging galaxies separated by late-(blue) and early-(orange) type. HDs are separated into the late- and early-type categories (see text for details).

Разбивка по морфологии







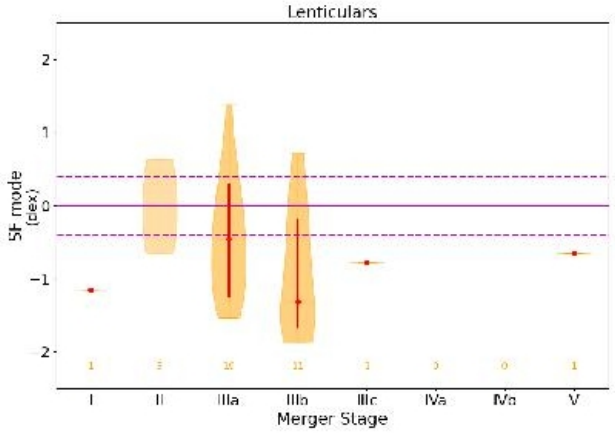


Fig. 6. Star formation mode distribution in each merger stage separated by morphology. From top to bottom: Spiral, HD (late- and early-type), elliptical, and lenticular galaxies. The solid- and dashed-magenta lines represent the MS. Numbers under each violin distribution shows the number of objects in each merger stage. For low N (≤3), shaded regions

Кто куда перетекает?
И перетекает ли?

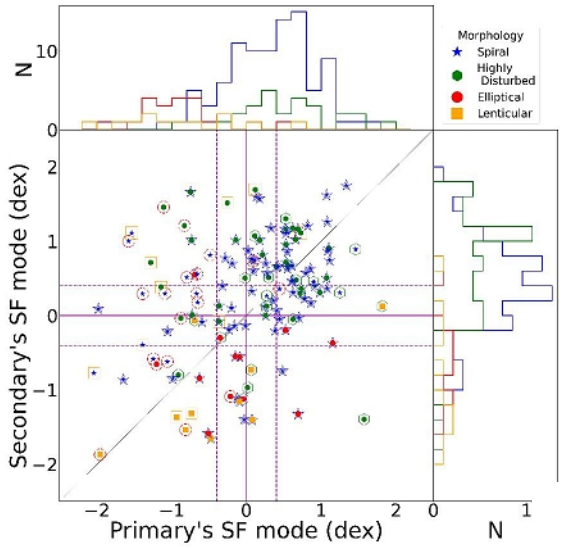


Fig. 7. Comparison between the SF mode of the primary and the secondary component. The coloured symbols show the m (unfilled symbols) and secondary (filled symbols) components as shown in the legend. The solid- and dashed-magenta li black line shows the one-to-one relation. The SF mode distributions of the primary and secondary component are shown i respectively. The SF mode distributions are coloured by morphology as shown in the legend.

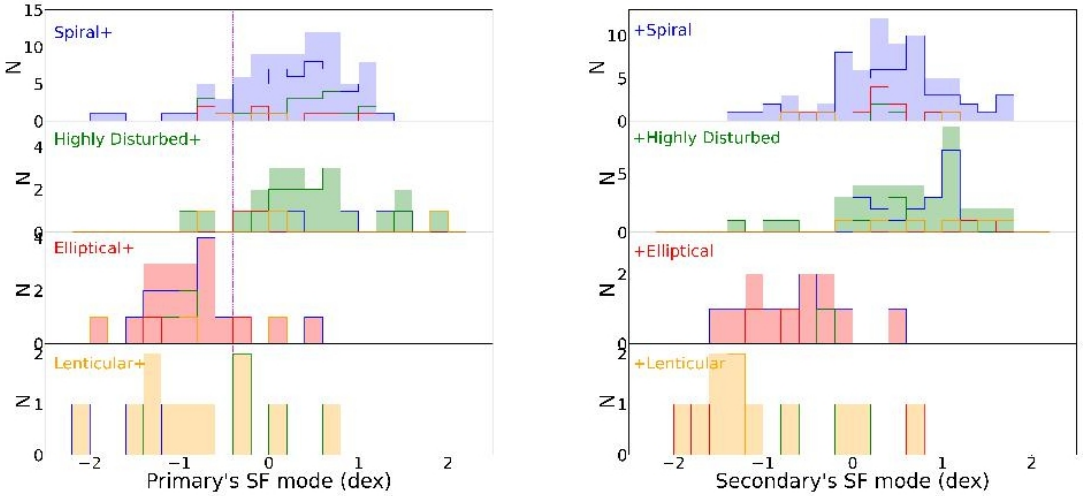


Fig. 9. SF mode of the primary (left panel) and secondary (right panel) component separated by their morphology. The filled distributions show the total distribution of the morphology. The unfilled distributions show the distribution of the companion's morphology.

Кто куда перетекает?
И перетекает ли?

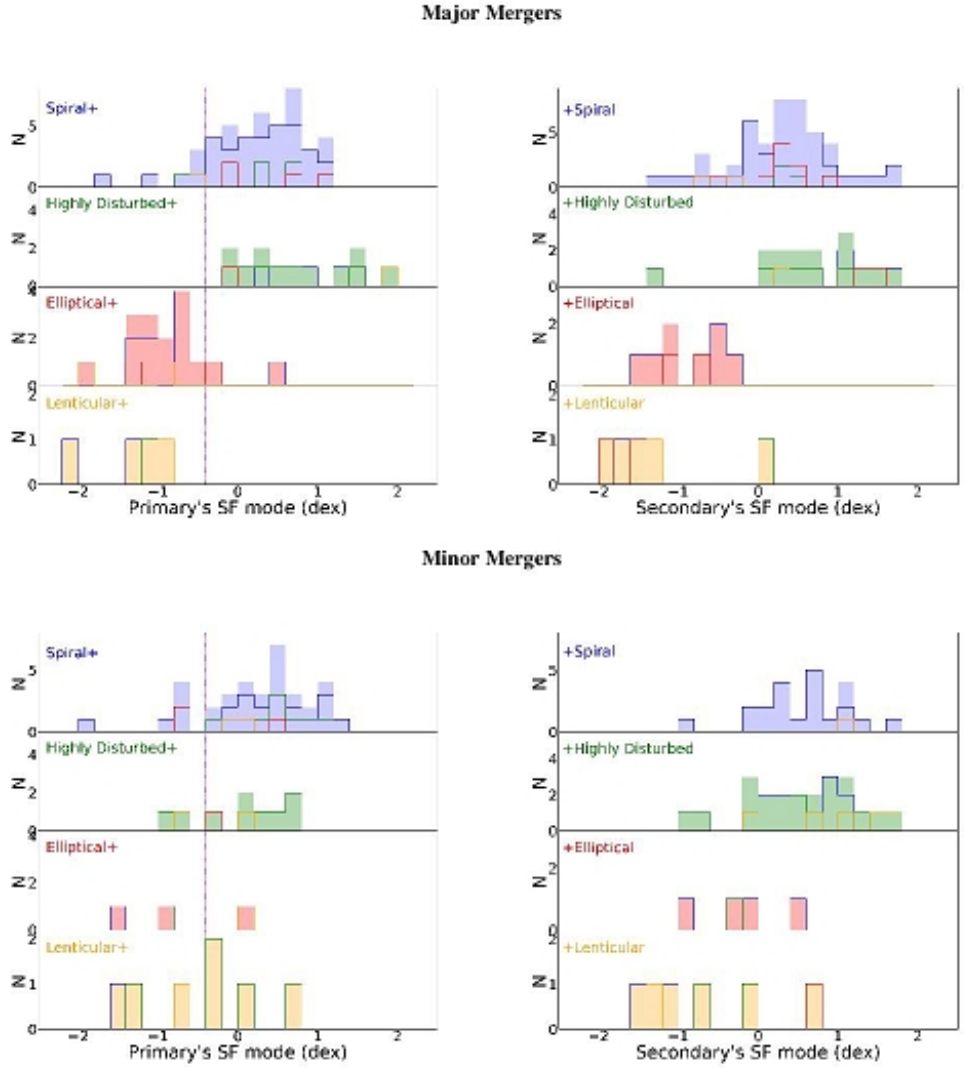


Fig. 10. As in Fig. 9. The left panels show the SF mode of the primary and the right panels show the SF mode of the secondary component, separated by major (top panels) and minor (bottom panels) mergers. The filled distributions show the total distribution of the morphology shown by the label in each panel. The unfilled distributions show the distribution of the companion's morphology.

Идентификация активных ядер

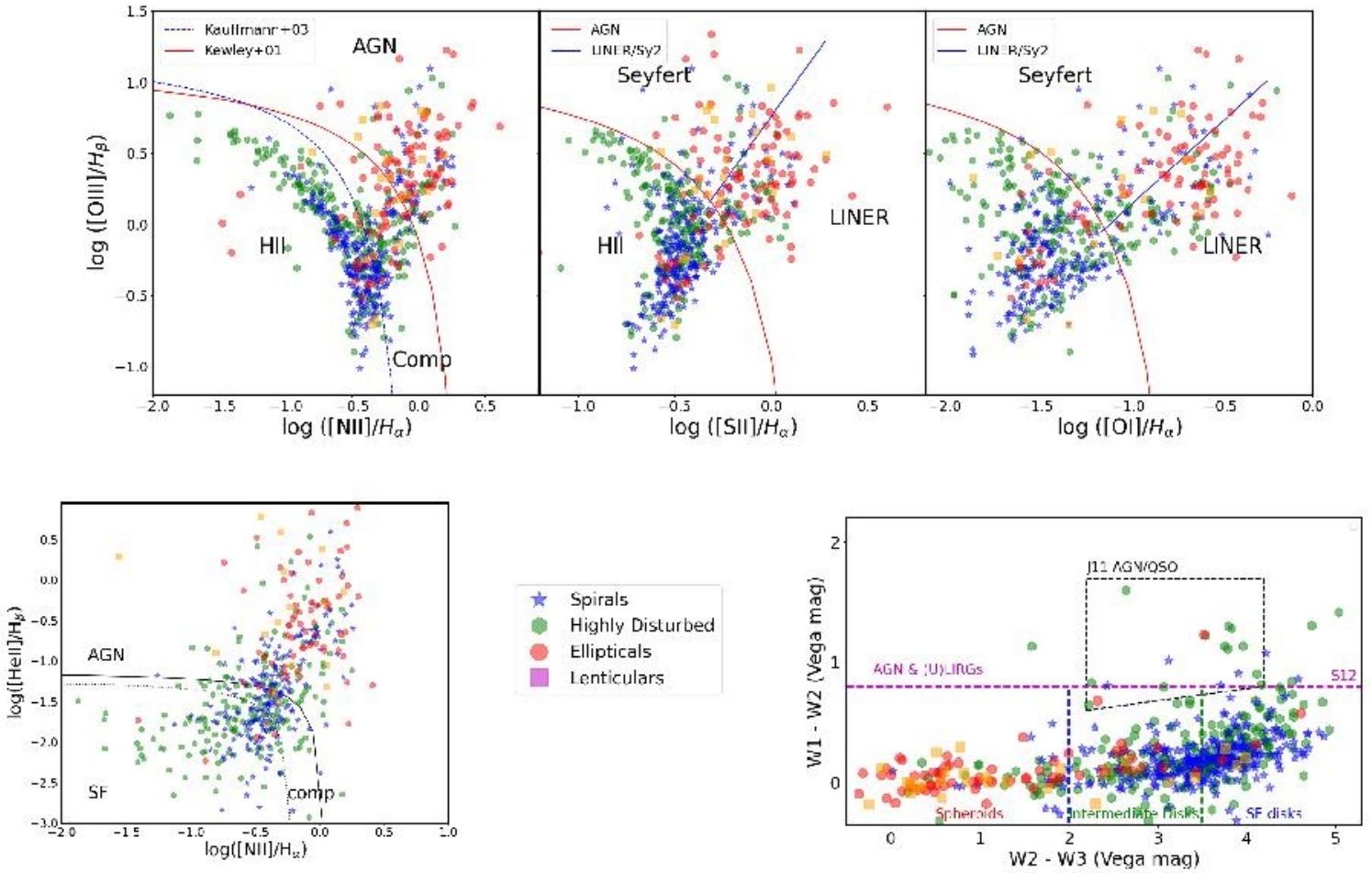


Fig. 11. *Top*: BPT diagnostic diagrams of the sub-sample that shows emission lines. Separations are shown in the legends. *Bottom – left*: Diagnostic diagram based on the HeII emission line. Separations defined by SB12. *Bottom – right*: WISE colour-colour diagram. Separations defined by J11 and S12. Mergers in the different panels are coloured by their morphology as shown in the legend.

Частота активных ядер падает по мере продвижения слияния

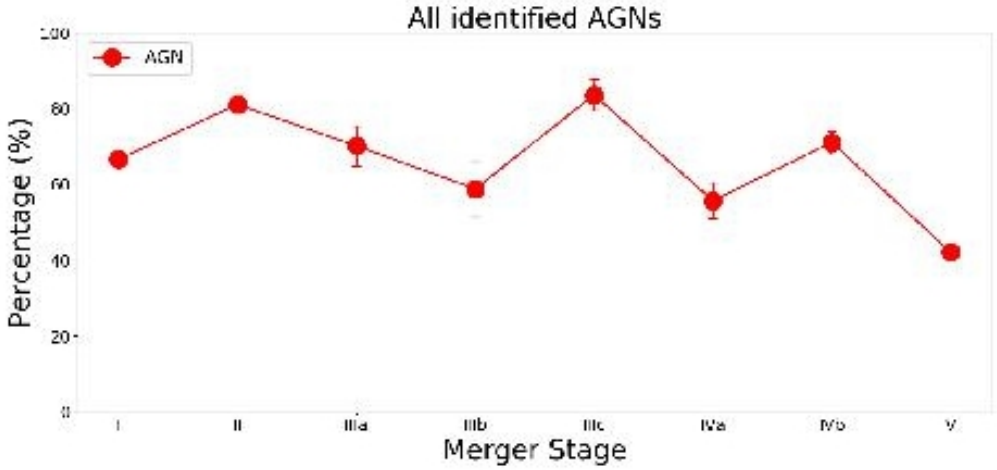


Fig. 12. Percentage of galaxies containing an AGN identified by either BPT-NII, BPT-SII, HeII or WISE diagram in each merger stage.

Из удивительных выводов:

- Звездообразование при слияниях усиливается; но событие намного длиннее, чем предсказывали модели.
- Что с перетеканием? Главная спиральная+вторичная эллиптическая → есть усиление; главная эллиптическая+спиральный спутник → нет усиления. Газовые мосты ликвидируются горячим газом гало?